REBAM® – getting past the limitations of seismic transducers to a more thorough root cause analysis of a rolling element bearing failure

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Bently Nevada recently had the opportunity to apply its REBAM System (see sidebar on page 9) to one of our own machines – an application with numerous similarities to other industries. The machine is a mobile chipper that processes logs up to 3 feet in diameter for use as mulch by Bently Biodynamics, Bently Nevada's sister company that makes high-quality compost from organic waste.

Figure 1a. Double row, rolling element bearing supporting the non-drive-end of the chipper drum.

The REBAM data was used to successfully identify a thrust loading problem on the double row, rolling element bearings that supported the 48 inch diameter, 50 inch long drum (Figures 1a & 1b) that is the heart of the machine. The application is one that demonstrates the unique capabilities of REBAM to provide data beyond the inner race, outer race, and element failure information associated with casing-mounted transducers. The data provided insight to the process and rotor-related problems that were the source of the bearing failure.

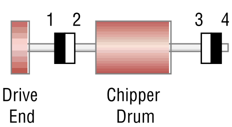


Figure 1b. Chipper bearing configuration.

REBAM data shows unusual bearing loading

The new chipper, on its first outing for Biodynamics, had demonstrated a bearing overheating problem associated with improper element clearances. Since the opportunity presented itself for increased insight into the operating conditions of the unit, shaft relative XY transducers and REBAM transducers (looking at each bearing row) were mounted at both ends of the drum. The low speed of the machine (from 800 rpm down to approximately 500 rpm, depending on the loading) and the high noise environment of the application were particularly suited to the REBAM System's capabilities. The transducers were connected to a Bently Nevada 3300 Machinery Protection System, with an annunciator in the machine cab.

On the machine's next job, the 3300 System immediately indicated that the bearings were operating outside the vibration limits that had been set, and a Machinery Management Services (MMS) Engineer was sent to document the data using the ADRE® for Windows Diagnostic System. Even before the data was printed from ADRE, it was obvious that the bearings were running in a failure mode; the timebase plots showed that the outer rows of the bearings were highly loaded and the inner rows were running essentially unloaded (Figure 2). For the operating frequency and condition of the bearing, the REBAM timebase plots gave a more intuitive presentation of the running condition of the bearing than a casing-mounted transducer could provide.

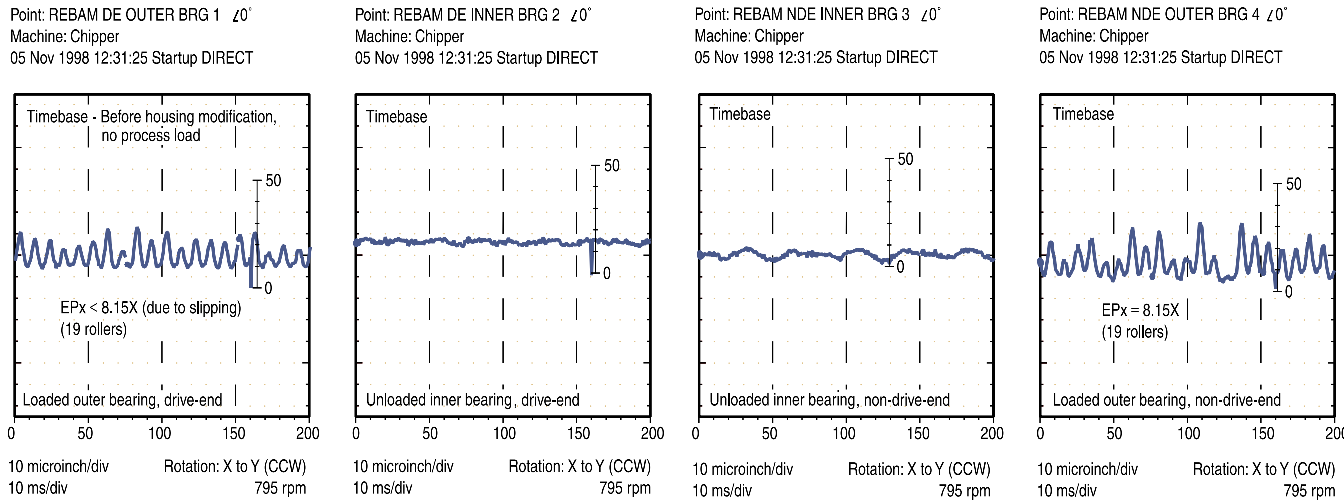


Figure 2a.

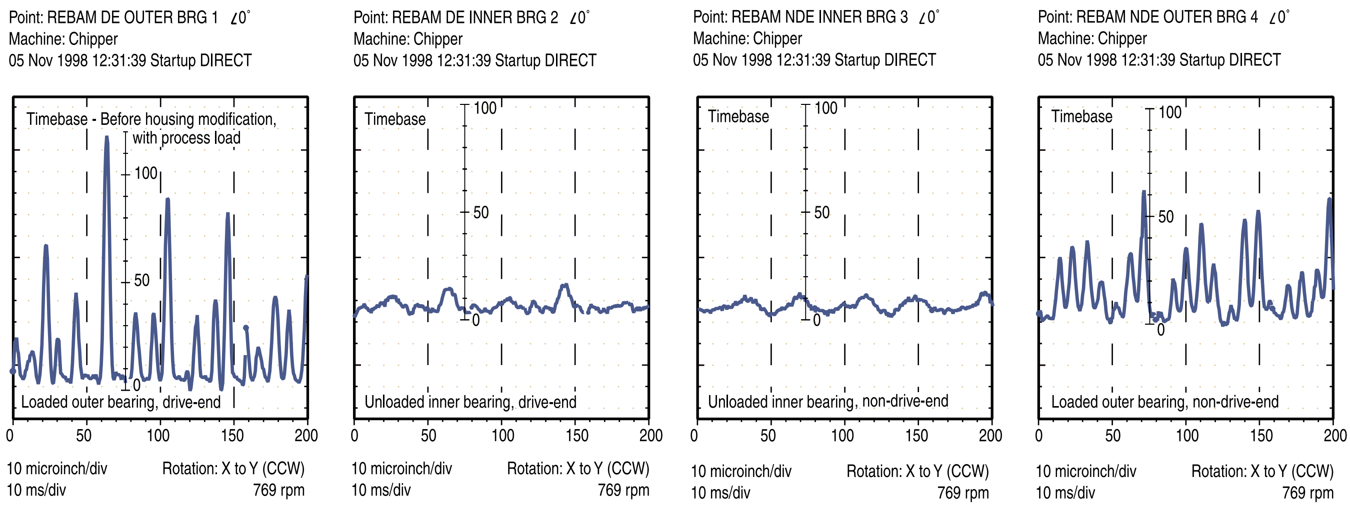


Figure 2b.

Figure 2. REBAM timebase plots of the bearing drive-end outer and inner rows and the non-drive-end inner and outer rows show the result of unrelieved axial thermal expansion which causes 360º contact between the elements and the outer races of the outer bearings. 2a) shows the element passage frequency (EPx) appearing on the outer rows (through the 1/2 inch thick outer ring) and not the inner rows of the bearings, even when there is no process load. The drive end bearing is slipping, so that the observed EPx is less than on the non-drive end. 2b) shows the amplitude of the element passage frequency modulated by the variable process load caused by the impact nature of the chipping process.

Thermal expansion source of bearing failure

The unit was returned to Bently Nevada, and the non-drive-end bearing was removed for inspection. The bearing exhibited considerable deterioration. It often seems that, when a pump or motor is sent for bearing replacement, it is returned and put back into service without considering possible external (rotor, process, lubrication, etc.) influences on the bearing's failure. In effect, the bearing gets replaced and everyone hopes that the unit will last a reasonable length of time before it has to be serviced again.

Admittedly, in this situation, casing transducers would possibly have identified an element or race problem, but would not have differentiated between inner and outer row dynamics. Why is this important? Because, in this case, it would have been easy to assume that the extremely rapid deterioration of the bearing was because it was not sized properly for the loading incurred. While a reasonable conjecture, this would have been an incorrect diagnosis and a needless bearing/machine modification would have ensued. Worse, it would not have addressed the real root cause, as we'll show

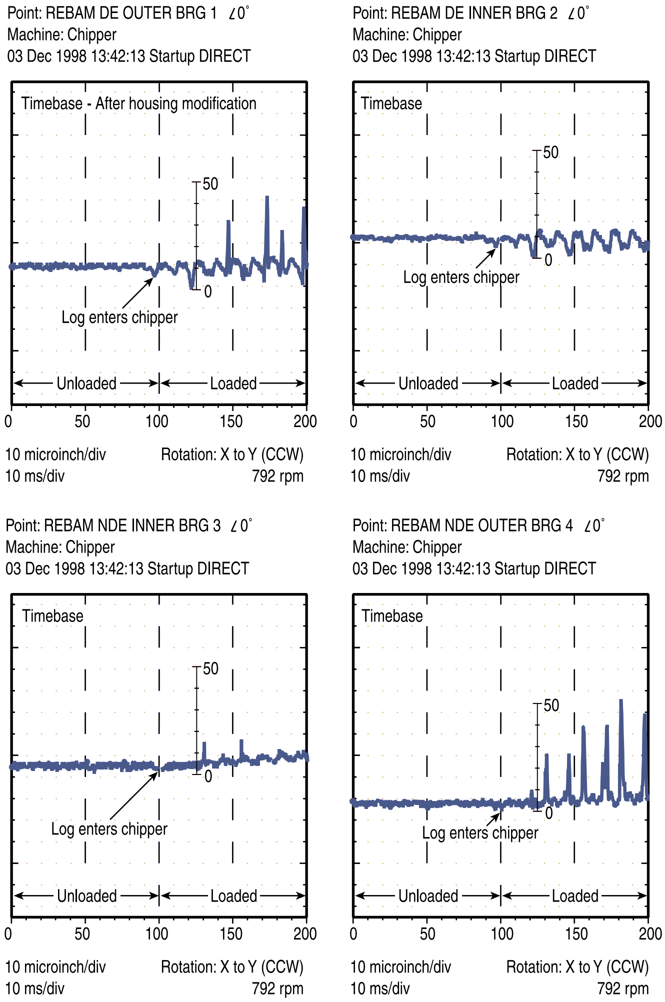


Figure 3. REBAM timebase plots showing more consistent loading of the inner and outer rows after the non-drive-end bearing is allowed to respond to axial thermal expansion.

in a moment. It brings to mind a statement once made by Albert Einstein, "For every problem, there is a simple answer that is wrong."

In contrast, the REBAM system, with its ability to directly observe each bearing row (something not possible with a casing-mounted transducer), showed significant element passage response through the 1/2 inch thick outer ring of the outer rows, even when the chipper was not processing a log (Figures 2a & b). This suggested that there was a constant 360° contact between the rolling elements of the outer rows and the outer races of the bearings. Unrelieved axial thermal expansion of the rotor would generate this condition and explain why the outer rows of the bearings would be loaded heavily in the axial direction while the inner rows would be essentially unloaded. (Normally the load zone would be at the bottom of the bearing when the chipper was idling and

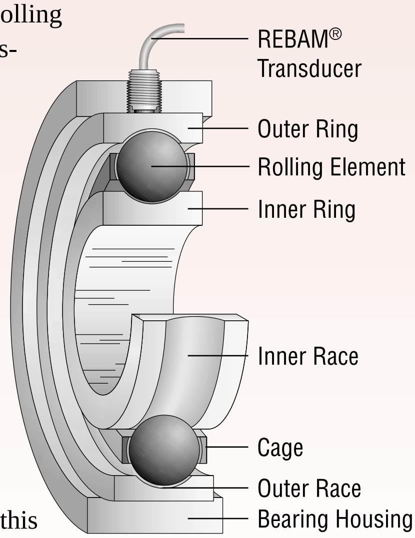
Back To Basics

Rolling Element Bearing Activity Monitor (REBAM®)

Bently Nevada's philosophy for monitoring and diagnostics of rolling element bearings is that 1) the monitor system will provide adequate warning to avert catastrophic machine failures, and 2) diagnostic data will be available, so that root cause (improper mounting, lubrication, loading, rotor, or process problems) analysis can be performed, and similar failures can be avoided.

A rolling element bearing, by design, has extremely small clearances, which do not allow a significant amount of shaft motion relative to the bearing. Forces from the shaft are transferred through the rolling elements to the outer race and then to the bearing housing.

The REBAM System has been available from Bently Nevada for over 15 years and is recognized, proven technology. It uses a high gain, low noise, eddy current proximity transducer to make direct vibration measurement at the outer ring. The installation can take into account the unique design, operation, and mounting configurations of the bearing, providing information that would be lost by the time it reached casing-mounted seismic transducers. The REBAM transducer measures the very small (microinch/micrometre) deflection of the outer ring as the rolling elements pass the area observed by the transducer. The operating frequency range for the REBAM transducer system is from 0 Hz to 10 kHz (0 to 600 kcpm). The REBAM System is a direct and very sensitive method of rolling element bearing measurement. It offers a very high signal-to-noise ratio compared to casing-mounted acceleration or velocity measurements.



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varying in direction around the outer race when the chipper processed logs.)

For rolling element bearings which support horizontal rotors, the static load zone, or load carrying area of the bearing, is determined by two parameters. First, the static weight of the rotor, which will act vertically downward to the bottom of the bearing. Secondly, the torque reaction force, which loads the bearing slightly to the left or right (depends on direction of rotation) of bottom dead center. The sum of these forces creates a load zone approximately 10-15 degrees left or right of bottom dead center.

In addition to the forces described above, a bearing will experience loading due to dynamic forces, such as unbalance. In the case of the wood chipper, dynamic forces during operation will also introduce impactive loading all around the inner and outer races. The dynamic load zone will move through 360 degrees.

Inspection of the bearing housings revealed that there was no provision for axial thermal expansion of the rotor. A quick calculation, based on a nominal 55º C (100º F) temperature rise, indicated the rotor could grow as much as 0.050 inch (1.27 mm). The bearing housing for the non-drive-end bearing was consequently modified to allow for this potential expansion, and a new bearing was installed.

Results of bearing housing modification

When the unit was put back into service after the bearing housing modification, the bearing temperature dropped from 77° C to 49° C (170º F to 120º F) and the REBAM data showed a significant decrease in the response of the four rows of elements (Figure 3) when the unit was under load. The element passage frequency so evident in Figure 2 has all but disappeared as the load zone varies due to the 4X impact nature of the chipper operation. The very high response of the outer rows (characteristic of the high axial loading of the bearing when there was no room for thermal expansion) had dropped to the same order of magnitude exhibited by the inner rows of the bearings. The loading on each row was now more equally shared by the bearing, as intended by the machine designer.

In addition to eliminating the rapid degradation of the bearing due to improper loading of the roller elements, a significant improvement in the efficiency of the unit was realized. Rolling element bearings, by nature of their design, have a friction-related horsepower consumption. This is minimized through adequate lubrication. When this bearing was improperly installed and could not accommodate axial expansion due to heating effects of the wood chipping process, the bearing subsequently ran at an elevated temperature. This was monitored with a temperature sensor in the grease-packed lubricant. The temperature was sufficiently elevated to liquefy the grease, which leaked out through the seals. The loss of lubricant increased friction effects and, therefore, consumed more horsepower. The properly installed bearing did not operate at elevated temperatures, did not initiate a loss of lubricant, minimized friction influences, and consumed less horsepower.

REBAM can get to root cause where other methods fail

The REBAM System demonstrated that it can offer data that isn't restricted to simple element passage problems. There are many other things that can be observed with REBAM transducers that offer a greater opportunity for more thorough root cause analysis. These include determining if the bearing is sufficiently designed to carry loads, verifying the loads, and verifying the activity of the bearing. A clear and resounding message from industry is that it is no longer sufficient to merely state that a bearing problem exists – the tools must exist to go to the root cause and prevent failures from occurring in the first place.

To reiterate our theme from this issue of the Orbit, "the right answers require the right data." REBAM clearly delivered the right data in this case and allowed Bently Biodynamics to treat the problem, not just the symptoms. For our customers, this means getting to root cause, fixing the underlying problem, and extending the Mean Time Between Repair on all rotating equipment.

If you are experiencing inadequate results with your present approach to rolling element bearings, it could be that you need a better, more direct, measurement. As this case history shows, there is a proven alternative in Bently Nevada's REBAM technology, supported by our Trendmaster® 2000 surveillance system, and in our continuous machinery protection and management systems.